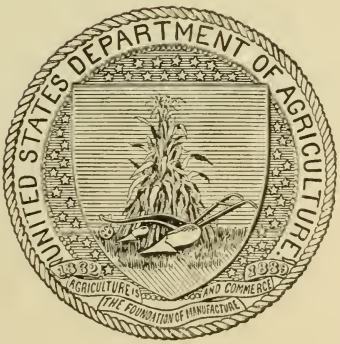
U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 127.
B. T. GALLOWAY, *Chief of Bureau.*

THE IMPROVEMENT OF MOUNTAIN MEADOWS.

BY

J. S. COTTON,
SCIENTIFIC ASSISTANT, FARM MANAGEMENT INVESTIGATIONS.

ISSUED APRIL 14, 1908.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1908.

BUREAU OF PLANT INDUSTRY.

Pathologist and Physiologist, and Chief of Bureau, Beverly T. Galloway.
Pathologist and Physiologist, and Assistant Chief of Bureau, Albert F. Woods.
Laboratory of Plant Pathology, Erwin F. Smith, Pathologist in Charge.
Investigations of Diseases of Fruits, Merton B. Waite, Pathologist in Charge.
Laboratory of Forest Pathology, Haven Metcalf, Pathologist in Charge.
Truck Crop Diseases and Plant Disease Survey, William A. Orton, Pathologist in Charge.
Plant Life History Investigations, Walter T. Swingle, Physiologist in Charge.
Cotton Breeding Investigations, Archibald D. Shamel and Daniel N. Shoemaker, Physiologists in Charge.
Tobacco Investigations, Archibald D. Shamel, Wightman W. Garner, and Ernest H. Mathewson, in Charge.
Corn Investigations, Charles P. Hartley, Physiologist in Charge.
Alkali and Drought Resistant Plant Breeding Investigations, Thomas H. Kearney, Physiologist in Charge.
Soil Bacteriology and Water Purification Investigations, Karl F. Kellerman, Physiologist in Charge.
Bionomic Investigations of Tropical and Subtropical Plants, Orator F. Cook, Bionomist in Charge.
Drug and Poisonous Plant Investigations and Tea Culture Investigations, Rodney H. True, Physiologist in Charge.
Physical Laboratory, Lyman J. Briggs, Physicist in Charge.
Crop Technology and Fiber Plant Investigations, Nathan A. Cobb, Crop Technologist in Charge.
Taxonomic and Range Investigations, Frederick V. Coville, Botanist in Charge.
Farm Management Investigations, William J. Spillman, Agriculturist in Charge.
Grain Investigations, Mark A. Carleton, Cerealist in Charge.
Arlington Experimental Farm, Lee C. Corbett, Horticulturist in Charge.
Vegetable Testing Gardens, William W. Tracy, sr., Superintendent.
Sugar-Beet Investigations, Charles O. Townsend, Pathologist in Charge.
Western Agricultural Extension Investigations, Carl S. Scofield, Agriculturist in Charge.
Dry-Land Agriculture Investigations, E. Channing Chilcott, Agriculturist in Charge.
Pomological Collections, Gustavus B. Brackett, Pomologist in Charge.
Field Investigations in Pomology, William A. Taylor and G. Harold Powell, Pomologists in Charge.
Experimental Gardens and Grounds, Edward M. Byrnes, Superintendent.
Foreign Seed and Plant Introduction, David Fairchild, Agricultural Explorer in Charge.
Forage Crop Investigations, Charles V. Piper, Agrostologist in Charge.
Seed Laboratory, Edgar Brown, Botanist in Charge.
Grain Standardization, John D. Shanahan, Expert in Charge.
Subtropical Laboratory and Garden, Miami, Fla., Ernst A. Bessey, Pathologist in Charge.
Plant Introduction Garden, Chico, Cal., August Mayer, Expert in Charge.
South Texas Garden, Brownsville, Tex., Edward C. Green, Pomologist in Charge.
Cotton Culture Farms and Farmers' Cooperative Demonstration Work, Seaman A. Knapp, Special Agent in Charge.
Seed Distribution (Directed by Chief of Bureau), Lisle Morrison, Assistant in General Charge.

Editor, J. E. Rockwell.
Chief Clerk, James E. Jones.

Farm Management Investigations.

William J. Spillman, *Agriculturist in Charge.*

Scientific Staff.—J. C. Beavers, D. A. Brodie, J. S. Cates, J. S. Cotton, H. R. Cox, M. A. Crosby, L. G. Dodge, J. A. Drake, L. W. Ellis, J. W. Froley, C. L. Goodrich, David Griffiths, Byron Hunter, H. B. McClure, A. D. McNair, H. A. Miller, W. A. Peck, C. E. Quinn, C. B. Smith, S. M. Tracy, J. A. Warren, B. Youngblood.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 17, 1908.

Sir: I have the honor to transmit herewith a paper entitled "The Improvement of Mountain Meadows," by Mr. J. S. Cotton, of the Office of Farm Management Investigations of this Bureau, and recommend its publication as Bulletin No. 127 of the Bureau series.

Experiments in reseeding mountain meadows were begun by this Bureau in 1902 and have been continued since that time. The results obtained enable us to draw a number of important conclusions concerning the practicability of reseeding ranges at high elevations in our Western States. Our experience also enables us to determine fairly accurately the cost of reseeding, the best manner for doing the work, and the resulting increase in the carrying capacity of the ranges. It is rather a striking circumstance that the only results of value that have been secured in these experiments have been with the ordinary tame grasses. Generally speaking, native grasses and forage plants have seed habits which render their artificial propagation on the ranges impracticable. Mr. Cotton has shown that mountain meadows may be reseeded at an expense which is commensurate with the returns to be secured.

The information contained in this bulletin should be of value to those who own ranges in the mountains or are responsible for their administration.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS

ILLUSTRATIONS.

B. P. I.—353.

THE IMPROVEMENT OF MOUNTAIN MEADOWS.

INTRODUCTION.

For a number of years the Bureau of Plant Industry has been carrying on investigations to determine what can be done to improve the stock ranges that have become badly depleted through overgrazing. In this work considerable attention has been paid to the grazing conditions in the mountains where the problem of summer pasturage is of very great importance in the production of beef and mutton.

A careful study of the conditions involved in these areas has led to two general conclusions: (1) On the mountain ridges, where the soil is usually very shallow and close to bed rock and is of a more or less sterile nature, very little can be accomplished in the way of range improvement. While reseeding may sometimes prove practicable, such improvement must ordinarily come through careful protection from overgrazing, in order that the original vegetation may be given a chance to restore itself. (2) In the mountain meadows and park-like areas, where there is ordinarily a good, rich, loamy soil, there are very great opportunities to increase the quantity of feed produced, and this increased production can very largely be secured by reseeding.

In connection with these investigations a range experiment station was established in the Wenache Mountains in Washington State in the fall of 1902, at which time seeding experiments were begun. These experiments were carried on cooperatively by the Washington Agricultural Experiment Station and the Bureau of Plant Industry. The following year other experiments were undertaken in the Sierra Nevada Mountains, California, the latter being under the direct charge of Mr. Charles H. Shinn, supervisor of the northern district of the Sierra National Forest. In 1906 further experiments were begun in the Warner Mountains in northeastern California, under the care of Forest Supervisor A. H. Hogue. In addition to these experiments numerous observations have been made on the results obtained by stockmen in various parts of the country in their efforts to improve the mountain grazing areas.

WENACHE MOUNTAIN STATION.

The Wenache Mountain station is located on the summit of the mountains, some 26 miles northeast of Ellensburg, and is at an altitude of a little more than 5,300 feet. It is highly typical of the entire mountain region along the eastern slopes of the Cascades in Washington. Practically all the different soil and climatic conditions found in this region are represented at the station or within a very few miles of it. The annual precipitation is probably not far from 20 inches and comes largely in the form of snow. The growing season does not much exceed four and a half months. The snow goes off some time between May 20 and June 1. The ground is usually frozen by the middle of October and snow falls to stay soon after November 1.

The station lies in the general course traveled over in the spring by the numerous migratory bands of sheep in going from the desert or lowland ranges to the high mountain pastures in the Cascades, and again in September on their return to the lowlands. As a result the region had been severely overgrazed for a number of years and the vegetation was in a badly depleted condition, much of it having been completely exterminated.

The station comprised a section of land that Babcock & Benson, the owners of a large sheep and cattle range, had inclosed with a good stock-proof fence as a holding pasture for their saddle and pack horses. As the problem of increasing the quantity of feed in the high mountain meadows was one of great importance to them, they donated the use of this section for experimental purposes. These men endeavored to keep out all stock from this area during those periods of the year when grazing might injure the grasses in the various plots, and in other ways did all they could to make the work successful.

SEEDING EXPERIMENTS.

The establishment of experimental plots at the Wenache Mountain station covered a period of two years. The first seeding was done in the latter half of October, 1902. The seed was sown so late in the season that there was no danger of its germinating that fall and yet in plenty of time for it to be on the ground before the snow, which began falling about two days after the seeding was finished. The melting snows in the spring tended to carry the seed into the ground and thus to insure germination.

Approximately 26 acres were seeded, plots of timothy, Kentucky bluegrass, redtop, mountain brome-grass (*Bromus marginatus*), and

white clover being started. In the spring of 1903 a little more than 30 acres were seeded. The same grasses were sown and a number of others, as follows: Orchard grass, brome-grass (*Bromus inermis*), cheat (*Bromus secalinus*), Italian rye-grass, perennial rye-grass, tall fescue, hard fescue (*Festuca duriuscula*), sheep's-fescue (*Festuca ovina*), Canada bluegrass, red clover, and alsike clover. The conditions at that time were highly favorable. The ground was covered with snow until June 1, 1903. On June 5 a warm wave swept over the eastern part of the State. This took the snow off very rapidly. The top of the ground dried out very quickly and it was necessary to cover the seed by means of a light harrow in order to insure germination. Later there were frequent showers which kept the ground moist and in excellent condition. By July 4 most of the plats were showing signs of germination. The majority of the grasses mentioned were again tested in the fall of 1903, a little more than 20 acres being seeded in the first half of October.

This completed the main part of the seeding, although in the fall of 1904 additional plots of tall fescue and orchard grass were started in order that the data obtained might be extended, while new plots of a few other grasses were established. The new plots were of slender wheat-grass (*Agropyron tenerum*), western wheat-grass (*A. occidentale*), tall oat-grass, and a native variety of sheep's-fescue (*Festuca ovina ingrata*).

In addition a number of plots were started on an area that had been plowed in the spring of 1904, the object being to determine how much value plowing has in the introduction of cultivated grasses in mountain areas.

MANAGEMENT OF STATION.

During the season of 1903 the proprietors of the land took a great deal of pains that all stock should be kept off the section until late in the fall. In the season of 1904 some 20 head of saddle horses were allowed to graze at the station from about the middle of June, the beginning of the growing season, until the first of November. Late in the autumn the station was also used for a few days at a time as a holding pasture for beef steers. Although the plots were very closely grazed in the late fall no harm was done them.

In June, 1905, the property changed hands, Coffin Brothers, who hold very extensive sheep interests in the State, purchasing it. These men very kindly offered to protect any part of the experiments that the Bureau of Plant Industry might desire. As all the seeding had been completed and the plots were well established, it was thought best to have them regularly grazed and learn how the different grasses

stood pasturing. Since that date the section has been grazed in about the same manner as formerly. No further attention has been paid to it by the Department of Agriculture than to make yearly observations as to the growth and pasturage qualities of the different grasses.

GRASSES TESTED.

Timothy.—Timothy was sown several times and under as many different conditions as possible, in order to give it a thorough test, 17 acres being seeded. Some of it was broadcasted on bare ground without further treatment, some was broadcasted and harrowed in, while a small quantity was sown on plowed ground. The quality of soil on which the seed was sown varied from a sterile side-hill soil, consisting largely of coarsely disintegrated basalt, to a good, rich, black loam. The rate of seeding was from 10 to 12 pounds to the acre.

On the half of the original plot started in the fall of 1902 where the seed was covered an excellent stand was secured. Had it been cut for hay it would have yielded in 1904 not less than 1½ tons per acre. It has been grazed quite extensively, especially in the fall, ever since the first year and it stood this grazing well until the season of 1906, when in some parts of the plot it seemed to be dying out. In 1907 it had entirely recovered and was doing fully as well as ever. (See Pl. II, fig. 2.) The stand on the unharrowed half of the plot was at first only about a fifth as good as on the other. By a natural process of reseeding, the stand on the greater portion has gradually thickened, until at the present time it is fully as good as that on the first half. The timothy sown in the spring of 1904 without covering failed for the most part to germinate. Where it was harrowed in, a fair stand was secured, but one that was in no way comparable with that on the area seeded and harrowed the previous fall. Here, also, the timothy has reseeded itself until the stand is now as good as can be desired. In 1907 these three plots, aggregating some 7 acres, would have cut fully 1½ tons of hay to the acre.

Half an acre of timothy was tested on the plowed ground. A good stand was secured, but it was no better than where the seed had been broadcasted and harrowed in.

Redtop.—A little more than 10 acres of redtop was sown in various parts of the section under practically the same conditions as the timothy. The rate of seeding was from 8 to 14 pounds to the acre. The first two years after seeding very little of this grass could be found, and except in a few scattered places the growth seemed to be unsatisfactory. By the summer of 1905 the stand had thickened greatly, there being on some areas a good sod where the first year after seeding there was apparently nothing to be seen. By

the year 1906 the stand on the greater part of the original plots was good. (See Pl. III, fig. 1.) The grass was then making an excellent growth and in many places was crowding out much of the original native vegetation. The redtop sown on the plowed area likewise gave an excellent stand and has done well. It is doubtful, however, whether the time saved in getting a stand of this grass would warrant the extra cost of plowing and preparing the land.

Tall fescue (*Festuca elatior*).—In the spring of 1903 an acre of tall fescue was seeded on good loamy soil where the original vegetation had been largely destroyed, its place being taken by yarrow and annual weeds. The rate of seeding was 24 pounds to the acre. This plot was duplicated the following fall. In the autumn of 1904 half an acre of the plowed ground was seeded to this grass. On half of each of the plots the seed was covered by harrowing. On those areas that were harrowed, a good stand has been secured and the grass has made an excellent growth. Tall fescue ranks next to timothy and redtop in value.

Orchard grass.—One and one-half acres of unprepared ground were seeded with orchard grass in the spring of 1903 at the rate of 24 pounds to the acre, the seed being harrowed in. In addition to this plot an area of one-sixth of an acre was seeded under similar conditions in the fall of 1904, while half an acre of plowed ground was seeded. The stand on the plowed area was quite satisfactory, but on the unprepared soil it was very poor. While it has been almost impossible to get a good stand, the orchard grass that came up has made a very satisfactory growth.

Brome-grass (*Bromus inermis*).—Two and one-half acres were seeded in the spring of 1903 on a rich, loamy soil, the rate of seeding being 22 pounds to the acre. One-half of the plot was harrowed. Where the seed was covered an excellent stand was secured. By the summer of 1905 the stand had thickened greatly, there was an excellent sod, and the grass was beginning to spread over some of the adjoining areas where there was a good soil. By the summer of 1906 it seemed to have disappeared in places in the main body of the plot, while along the edges it appeared to be getting much more abundant. In 1907 there was an excellent stand on nearly the entire plot.

Mountain brome-grass (*Bromus marginatus*).—About 6 acres were seeded to mountain brome-grass at a rate of 25 to 30 pounds to the acre. As this grass is a native of these mountains and naturally grows on the loose, gravelly soil areas, the plots were located on such areas. Where the soil was very poor a stand as satisfactory as could be expected was obtained. On a plot of one acre where the soil was somewhat coarsely disintegrated and where the seed had been harrowed in, a stand was secured that, if cut for hay, would have yielded not less than three-

fourths of a ton of hay per acre. (See Pl. III, fig. 2.) Considerable seed has been collected from this plot for experimental uses in other places. One-half acre of this grass was tested on plowed ground. The stand on the plowed area was no better than that secured on the original plot, where the seed was merely harrowed in. The stock on the section have never grazed this grass to any extent, as there were other grasses that are much more palatable growing near it.

Cheat (*Bromus secalinus*).—One acre was seeded to cheat in the spring of 1903 on an open park-like area where the soil was a good black loam and where mountain clover (*Trifolium longipes*) formed the prevailing vegetation. The rate of seeding was 30 pounds to the acre. The plot was duplicated in the fall. The grass seed germinated well where it was harrowed in, but the grass made a very poor growth and by the season of 1907 had entirely disappeared.

Kentucky bluegrass.—Eleven acres were seeded to Kentucky bluegrass at three different seasons, the rate of seeding varying from 14 to 18 pounds to the acre. Except for a small plot of about one-tenth acre on plowed ground this grass made almost no growth until the summer of 1906. At the time it was apparent that the grass had started in occasional small patches and was making a fair growth and furnishing a little pasturage. The indications were, however, that it would be of very little value.

Canada bluegrass.—A little more than 3 acres was sown to Canada bluegrass in the spring and fall of 1903, the rate of seeding varying from 20 to 25 pounds to the acre. The grass was seeded in an open park-like area where the soil was for the most part a rich black loam. One-half of each plot was harrowed. A fair stand was secured on the area that was harrowed, but until the season of 1906 it made a very poor showing. By that time the stand had greatly improved and the grass seemed to be making a much better growth than in previous years. This grass will, however, be of very little value in mountain meadows.

Perennial and Italian rye-grasses.—Some two or more acres were seeded to each of these grasses in the spring and fall of 1903. The conditions under which they were sown were typical of the majority of the plots at the station. In both cases the stand secured was poor. Both grasses made very little growth and soon ran out. They seem to be totally unadapted to this region.

Hard fescue (*Festuca duriuscula*).—About 2 acres were seeded to hard fescue in an open park in the spring and fall of 1903. In addition, a small plot of one-sixth acre of plowed ground was seeded. No traces of this grass could be found on the main plot. The stand secured on the plowed ground was excellent at first, but the grass has been gradually running out and by the summer of 1907 there was very little left.

Sheep's-fescue (*Festuca ovina*).—Some 3 or 4 acres were seeded to this grass during the spring and fall of 1903, 16 pounds of seed being used to the acre. A fair stand was secured, but the grass does not seem to have done very well. In fact, it has not made nearly the growth that is made by a variety of sheep's-fescue (*Festuca ovina ingrata*) native in these mountains.

Native sheep's-fescue (*Festuca ovina ingrata*).—One-fourth of an acre was seeded to this grass in the fall of 1904. This grass, locally known as bunch bluegrass, is a native of the Wenache Mountains and the seed was hand gathered. The rate of seeding was 16 pounds to the acre. Apparently the seed never germinated.

Slender wheat-grass (*Agropyron tenerum*).—In the autumn of 1904 a plot of one acre of this grass was sown in an area where all the original vegetation had been destroyed by overgrazing and trampling and where yarrow and weedy annuals had become quite abundant. The seed was harrowed in. In addition to this, a plot of about one-fourth of an acre of plowed ground was seeded. The grass on the acre plot started very slowly, and even in the summer of 1906 seemed to be a failure. By 1907 it had become much more abundant, and although the stand was still quite poor it looked promising. A very good stand was secured on the plowed area and the grass has made a satisfactory growth. In the summer of 1907 it was estimated that this plot would have yielded, if cut for hay, a crop of nearly three-fourths of a ton to the acre. The experiments indicate that this grass may have some value in reseeding some of the hillside areas of the mountain regions. They will, however, need to be continued two or three years more before definite conclusions can be reached.

Western wheat-grass (*Agropyron occidentale*).—Two small plots were seeded to this grass in the fall of 1904, one on plowed ground and one on an area with good soil where the original vegetation had been destroyed by overgrazing. The seed failed to germinate on the unprepared ground. A fair stand was secured on the plowed area, but it has not made a very thrifty growth. This grass will probably be of no value in the high mountains.

White clover.—About 10 acres were seeded to white clover under conditions identical with those found on the timothy and redtop plots. The rate of seeding was from 8 to 12 pounds to the acre. Very few signs of germination of this seed have ever been found. In view of the fact that an excellent stand was secured from this same seed on the Cooke & Bull holding pasture two years later, the blame for this can not be placed on the quality of the seed. Various observations would indicate that the failure of this plant was probably due to lack of the proper kind of nitrogen-gathering bacteria in the soil.

Red clover.—A plot of 1½ acres was seeded to red clover in the spring of 1903. Wherever the ground was not too wet the seed was harrowed in. A fair stand was secured on the drier part of the plot, but it became poorer each year until by the season of 1906 the clover had entirely disappeared. A small plot was tested on plowed ground with similar results.

Alsike clover.—Two acres were seeded to alsike clover in the spring and fall of 1903, the rate of sowing being 15 pounds to the acre. An excellent stand was secured from the spring sowing. Up to the season of 1905 it still remained alive, but had made very little growth and seemed to be inferior to the native clover. It had a yellow and unhealthy appearance and showed an entire lack of the root tubercles. By the year 1906 about three-fourths of the clover on this plot had disappeared. The remaining fourth of the plants had made a much larger growth and showed a much healthier condition than in previous years. In 1907 it had entirely disappeared. It is quite possible that if the seed had been inoculated this clover might have proved a success.

Vetches.—A number of vetches were experimented with, most of them being tested on plowed ground. They all failed to germinate.

EXPERIMENTS OF BABCOCK & BENSON.

In addition to the experiments already described, in the latter half of October, 1902, Babcock & Benson scattered 1,000 pounds of timothy seed, 400 pounds of orchard grass, 150 pounds of Kentucky bluegrass, and 100 pounds of white clover over the section and the park-like areas of their 14-section beef pasture adjoining it. At first there were very few signs of this seed having germinated, but by the year 1904 it was quite noticeable that a good deal of the timothy and some of the orchard grass had caught and that they were doing well. The timothy became more abundant each year until by the summer of 1907 it was pretty well distributed over the entire section. There are at the present time numerous spots a rod or more square where the stand is sufficiently thick to cut for hay.

The orchard grass has made a fair showing, but hardly sufficient to repay the cost of the seed. The Kentucky bluegrass and the white clover were complete failures.

EXPERIMENTS ON THE COOKE & BULL CATTLE RANGE.

The experiments on the Cooke & Bull cattle range were undertaken in order to test the adaptability at a lower altitude of some of the grasses that had been tried at the Wenache Mountain station. The place selected is in a holding pasture at an elevation of approximately 4,000 feet. It is located some 6 miles southeast of the

Wenache Mountain station. The sowing was done in small meadow-like areas at the head of a large canyon, where for the most part there was a good loamy soil, and in the bottom and along the sides of the canyon. The entire region in which this tract lies has been badly overgrazed for years by numerous bands of migratory sheep on their journeys to and from the mountain pastures. As a result, practically the whole area where the seed was sown had been denuded of all vegetation except shrubs and trees. The principal grasses experimented with were timothy, redtop, and white clover.

Timothy.—Timothy was sown on approximately two acres in a meadow-like area at the head of Perkins Creek canyon in the fall of 1904. The seed was broadcasted at the rate of about 8 pounds to the acre without further treatment. The following fall about 50 pounds of this seed were scattered along the bottom and sides of the two forks of Perkins Creek canyon, near the head. In spite of the fact that a large number of cattle have been kept on this pasture at various times and that it has been closely grazed, the timothy in the original plot has retained an excellent stand. If it could be protected, this plot would yield a good crop of hay. There is also a good stand of this grass along the bottom of the canyon and it promises to make an excellent growth.

Redtop.—A small plot was seeded to redtop near a spring just below the forks of the canyon in the autumn of 1904. The following fall (1905) about 50 pounds of this seed were scattered along both forks of the canyon, approximately the same area being used as for timothy.

By the spring of 1907 the redtop in the plot looked highly promising. Where the seed had been scattered along the canyon there was considerable of this grass to be seen. By the season of 1908 it will be sufficiently established, judging by the small plot, to produce a considerable quantity of feed.

White clover.—A considerable area in the main branch of the canyon was seeded to white clover in the fall of 1904 and again in 1905. There is an excellent stand, and in spite of its having been heavily grazed the clover has been making a good growth. It is somewhat questionable whether white clover produces enough forage under such conditions to make it of much value.

Other grasses.—In addition to the grasses mentioned, perennial rye-grass, Italian rye-grass, and Kentucky bluegrass were tested under similar conditions. These have yielded negative results.

RESULTS OF RESEEDING INVESTIGATIONS.

The experiments of the Bureau of Plant Industry show quite conclusively that the depleted mountain meadows (Pl. I, figs. 1 and 2) can be brought back to their original carrying capacity in two to

three years' time by reseeding with tame grasses. (See Pl. II, fig. 2, and Pl. III, figs. 1 and 2.) There are numerous instances, notably in the Cascade Mountains of Washington, where by the introduction of such grasses the meadows can be made to produce more forage than they ever did.

Out of the thirty or more grasses and forage plants tested, there are seven—tall fescue, orchard grass, brome-grass, mountain brome-grass, slender wheat-grass, timothy, and redtop—that have shown themselves to be of some importance in the restoration of mountain grazing areas. Timothy and redtop have proved to be of great value for this purpose. These two grasses can be introduced at a comparatively small cost, will furnish satisfactory yields, and will readily withstand moderately heavy grazing.

In addition to carrying on the experiments here described the writer has spent considerable time in studying the forage problems in the Cascade and Sierra Nevada Mountains and in making careful observations as to what has been accomplished by various stockmen and farmers in reseeding mountain meadows in that region. Several of these men have greatly increased the quantity of forage produced in such meadows by seeding them down to either timothy or redtop or a combination of the two. There are also a number of instances where these men are raising good crops of hay with which to supply the various lumber, mining, or tourist camps. Other investigations carried on by members of the staff of the Bureau of Plant Industry show that these grasses can readily be established throughout the Rocky Mountain system. In fact, they are quite widely scattered through the hauling of hay to the various mining and lumber camps and also through systematic effort on the part of some of the stockmen living in that region.[a] The results obtained by these various stockmen show that there are numerous meadows throughout the entire western mountain region where timothy and redtop can be very successfully grown. They also prove that it is a paying proposition to seed down such meadows.

TIMOTHY.

Timothy will be of great value in restoring those areas where there is a fairly deep, rich soil that has been denuded of vegetation by overgrazing and trampling. Plate I, figures 1 and 2, shows portions of two different mountain meadows that are typical of just such results. This grass can also be used to advantage in those places where the mountain clovers naturally grow. (See Pl. IV, figs. 1 and 2.)

[a] See Bulletin No. 117 of the Bureau of Plant Industry, U. S. Department of Agriculture, p. 11.

An example of what can be accomplished by the use of this grass is shown in Plate II. Figure 1 of this plate shows a part of a meadow near the Wenache Mountain station, lying just outside of the station fence. This area has been protected from overgrazing during the past five years, and as a result it is restored to a point where it will probably carry nearly as much stock as it originally did. Plate II, figure 2, shows a part of the same meadow lying just within the fence. This area was seeded to timothy in the autumn of 1902. The carrying capacity of the area seeded down is undoubtedly two or three times greater than that not seeded.

It is recommended that from 8 to 10 pounds of seed be used to the acre. This will give a stand that will be good enough to cut for hay. (See Pl. II, fig. 2.) If it were necessary to economize, a rate of 6 pounds per acre might prove sufficient, but the stand secured would, of course, not be as good as where a little higher rate of seeding was used. Although stands that have been entirely satisfactory have been obtained in places that have been subjected to continuous grazing, better results will usually be obtained if the seeded area can be protected during the first season or at least until the grass has become firmly rooted.

If the maximum rate of 10 pounds to the acre be used, the seed at 6½ cents a pound will cost 65 cents. The labor, provisions, and cost of hauling will bring the entire expense to about 95 cents an acre. The plots at the Wenache Mountain station have given a yield that if cut for hay would have averaged more than a ton to the acre. While the experiments have been carried on under practically typical range conditions it is possible that they have been a little better protected than they would have been in a large inclosure. Granting that these results are better than will be obtained under all circumstances, it is reasonable to believe that in an ordinary mountain meadow where there is a fairly deep and good soil a yield equivalent to at least half a ton of hay to the acre can be secured. Observations of the results obtained by practical stockmen will tend to confirm this conclusion. If the yield is equivalent to only half a ton it will still mean that the carrying capacity of this land has been increased so that an acre will carry a 1,200-pound steer a little more than 30 days longer than it previously did. If we value pasture at 25 cents a head each month this would, after the first year, give a return of more than 25 per cent on the cost of seeding.

In this connection an estimate has been made in order to show what can be accomplished by reseeding a pasture that is within some 5 or 6 miles of one of the above-mentioned experiment stations. This pasture has been carefully watched during the entire four years and

it is doubtful if its carrying capacity is as high as it was previous to fencing. The field contains approximately 1,100 acres and carries about 100 head of stock of all ages during the five summer months. It is a typical mountain pasture, the ridges consisting largely of "scab" land—land where there is very little soil—and the hillsides and bottoms of the canyons having a good, deep, rich soil. There are at least 300 acres of this pasture that could be seeded to timothy to good advantage. Using the same figures, the cost of seeding this area would be as follows:

3,000 pounds of seed at 6½ cents a pound	$195
Labor at $1.50 a day	45
Provisions	15
Cost of hauling seed, provisions, etc	20
Total	275

If we estimate, as above, that a stand sufficient to yield half a ton of hay to the acre is secured, the pasture by the second summer after seeding will be in position to support 60 additional head of cattle, or nearly two-thirds more than at present, through the grazing season of five months.

Considering pasturage worth 25 cents per month per head, this pasture will be in a position to yield a return of more than 25 per cent a year on the expense of seeding it down.

As a result of these investigations two stockmen who have extensive holdings in the mountain grazing areas have sown timothy in their mountain meadows. These men are much pleased with the results obtained and consider that the grazing capacity of their meadows has been sufficiently increased to make reseeding a very paying investment.

REDTOP.

Redtop will also be of value in the improvement of mountain meadows. It can be used to advantage under the conditions shown in Plate I, figures 1 and 2, but will be most useful in reseeding those places that are too wet for timothy. It will do well on those areas where timothy grows successfully, and in the Sierra Nevada Mountains of California will apparently make a very good growth where it is a little too dry for timothy.

The most serious objection to this grass is that it is very slow in getting started, especially in the high altitudes. (See Pl. III, fig. 1.) It will be necessary to wait at least three years before redtop will make much of a showing. Once established it is there to stay. These investigations have shown that not only will this grass remain permanently, but it will gradually become thicker in that part of the

meadow in which it is sown and will in time spread through the meadow, eventually crowding out much of the native vegetation.

From 10 to 15 pounds of seed of the very best quality should be used to the acre. If the seed is full of chaff this rate should be doubled.

Although no experiments in mixing this grass with timothy have been made, it is reasonable to believe that such a mixture might prove valuable. The timothy would be available for pasturage the second summer after seeding and for a number of years thereafter. The redtop would not be well enough established to yield any returns before the third or fourth year. Once started it would continue to become more abundant and would remain permanently even though the timothy might run out.

TALL FESCUE.

Were it not for the fact that the seed of this grass is very expensive and that timothy can be established at a much less cost, tall fescue would in all probability play an important part in range improvement. It gives good yields, stands grazing well, and is a favorite with stock, as they prefer it to either timothy or redtop. Of all the grasses tried at the Wenache Mountain station it has proved third best. This grass should be sown at the rate of 25 pounds to the acre, and if not too expensive it would be advantageous to harrow it in.

ORCHARD GRASS.

The investigations made in California indicate that orchard grass can probably be used to advantage in improving the mountain grazing areas of that State. In Washington this grass has made a very good growth, but it has been very difficult to get a good stand of it.

Orchard grass will be of most value on those areas that are a little too dry for the successful growth of timothy, such as the outside edges of mountain meadows. (See Pl. IV, fig. 1.) As there seems to be considerable difficulty in getting a stand, a heavy rate of seeding, not less than 25 pounds to the acre, should be used. If possible, the seed should be harrowed in.

BROME-GRASS.

Like tall fescue, brome-grass has shown itself worthy of consideration in reseeding mountain meadows. It has given a good stand and made an excellent growth. Of all the grasses tested it has been the favorite with the stock pastured on the section, and as a consequence has at times been very heavily grazed. It has readily with-

stood the occasional overgrazings and the stand has improved each year.

At the present price of the seed (about 11 cents a pound) it is doubtful from a range standpoint whether it can be used profitably. Not only is the seed expensive, but good results require that it be harrowed in. Although its cost makes it prohibitive for use alone, it might be a good plan to sow a little of the seed along with timothy. Once established, the brome-grass would have a tendency to thicken and would probably be permanent.

MOUNTAIN BROME-GRASS.

This grass is a native of the mountains of the Western States. It formerly grew quite abundantly on the gravelly hillside areas of these mountains, but has been largely exterminated through overpasturing. The experiments at the Wenache Mountain station show that it can easily be reseeded and that an excellent stand can be secured. Investigations made in the Warner Mountains of California confirm this conclusion. As the seed is large and heavy it should be sown at the rate of 25 pounds to the acre. While mountain brome-grass can be reintroduced by merely reseeding the ground, the best results will be obtained if the seed is harrowed in. Next to timothy this grass has made the best growth of any of those included in the experiments here recorded. From the standpoint of yield and as a grass to cover the denuded side-hill areas, it will prove entirely satisfactory. (See Pl. III, fig. 2.) Its chief drawback lies in the fact that stock will not eat mountain brome-grass readily when they can find more palatable feed. The plot at the Wenache Mountain station has been grazed but very little. It has, however, been located near others bearing grasses that are naturally favorites with stock. In contrast to this it is noticeable that whenever this grass occurs on the open range or in places where there is not an overabundance of feed, it is readily eaten.

SLENDER WHEAT-GRASS.

As the experiments tried at the Wenache Mountain station with slender wheat-grass were not begun in the fall of 1904, the plots are not old enough to draw definite conclusions. There are, however, strong indications that this grass will prove of considerable value in reseeding gravelly hillside areas.

Extensive experiments are now being carried on with this grass in the Warner Mountains of California to determine the practicability of using it in the restoration of the overgrazed gravelly areas of the mountain sides at high altitudes. These experiments are under the direct charge of Mr. A. H. Hogue, supervisor of the Warner Moun-

tain National Forest. If they succeed this grass will be of great value in the improvement of such areas, as it is greatly superior to mountain brome-grass, being much more palatable to stock and also more nutritious.

CLOVERS.

At the present time the clovers can not be recommended in improving mountain meadows. In all the experiments at the Wenache Mountain station they have been complete failures. During the first two years of its existence the alsike clover gave an excellent stand. It made a very poor growth, however, and finally died out.

The white clover tried at the Wenache Mountain station both in the plots and by Babcock & Benson proved a failure. On the Cooke & Bull range, which is from 1,000 to 1,500 feet lower, the very same seed has given a fairly good stand, but it has not as yet made a very large growth.

METHODS OF RESEEDING.

In this work the writer has obtained the best results by using a hand seeder such as is commonly used in seeding alfalfa. With such a machine a man can easily sow from 10 to 12 acres a day. This acreage can be greatly increased, especially in scattered areas, if a saddle horse is used and the sowing is done on horseback.

If the seeding is done in wet meadows, where there is more or less standing water, it will probably be best to wait until late spring or early summer when the ground and soil water are so warm that the seed will germinate. The grass will then become sufficiently established to withstand the coming winter. In sowing timothy and redtop, except on very wet areas, the best results will be obtained if the ground is seeded late in the fall just before the snow falls. At that time there will be no danger of the seed sprouting and being killed by cold weather. The following spring the melting snows will tend to carry the seed below the loose, mulchy soil to the moist compact soil beneath. Continued observation has shown that this loose, mulchy soil becomes too dry on top for the germination of seed almost as soon as the snow is gone and within a very few hours after a shower. It is therefore essential that the seed be gotten under the mulch by some such means as the melting of snow, a heavy shower, or harrowing. These grasses can be seeded in the spring, but unless there are very favorable rains it will be necessary that the seed be harrowed in, if the work is to be successful. Where the seed is rather large, as is the case with brome-grass, orchard grass, and slender wheat-grass, it is probable that the extra stand secured will justify the extra cost of harrowing.

Plowing and a thorough preparation of the soil are advocated by some. If the cost of getting the plow into the high mountains and of operating it there be taken into consideration, this method will ordinarily be found impracticable. The results obtained at the Wenache Mountain station show that, with the exception of slender wheat-grass and orchard grass, the stands secured on plowed ground have been very little, if any, better than where the seed was merely harrowed in. Not only is plowing unnecessary, but under some circumstances it would be positively injurious. There are numerous mountain meadows which are practically surrounded by hills that have been denuded of vegetation by overgrazing. To plow such a meadow would be a very dangerous proceeding. The instant the soil is loosened the first rush of water from these hills after a heavy rain or a spring freshet will carry all the soil away and completely ruin the meadow.

OTHER IMPROVEMENTS.

While reseeding is the main factor in the improvement of mountain meadows there are three other means that under some circumstances can be used to advantage and will be of considerable importance in making the reseeding pay. These are (1) the drainage of meadows that are too wet, (2) the filling in of old washouts, and (3) irrigation.

DRAINAGE.

Many mountain meadows, especially in high altitudes, are too wet for the growth of suitable forage. The prevailing vegetation consists of sedges, rushes, and other water-loving plants. The quality of this feed is very poor. If these meadows can be properly drained the native vegetation growing on the drier areas, which usually has a much higher forage value, will gradually work into the drained areas and supplant the original vegetation. This will bring about a very great improvement in the quality of feed produced. After the meadows have been drained it is recommended that they be seeded down to either timothy or redtop, especially if they have been subjected to overgrazing in the past. The combined drainage and seeding will result in greatly increasing the carrying capacity of the meadows. Not only will there be more forage, but it will be of much better quality.

This method of improvement must be used with a great deal of care, for if the draining is not properly done it may result in the destruction of the meadow. Pains should be taken to see that the drains are not cut too deep and that there is no danger from future washouts. If such a meadow is surrounded by steep hills that have been denuded of vegetation so that there is danger of a sudden rush of water, it will be much safer to leave it undrained.

FILLING IN WASHOUTS.

A large number of mountain meadows are not producing nearly the quantity of feed they formerly did. Ordinarily this is because the meadows and the surrounding hills have been too severely overgrazed in years gone by. As a result the water from the melting snows or from rains goes out with a rush and the little creeks that run through these meadows have cut deep channels. Plate IV, figure 2, shows such a cut in the process of formation. These cuts serve as drains, but being too deep draw off the ground water too far beneath the roots of the vegetation. This results in the death of the vegetation or in greatly lowering its rate of growth. It also enables many drought-resistant weeds that are of little forage value to get a foothold and crowd out the original vegetation.

Some of these meadows could be restored to their former carrying capacity by throwing dead logs, brush, and other rubbish into the creeks at intervals. This rubbish will tend to catch the silt that washes down, and thus gradually fill up the cuts that have been formed. This has been very successfully done in the mountains of California in one or two instances that have come under the writer's notice.

IRRIGATION.

There are a number of mountain meadows where the quantity of forage produced (Pl. IV, fig. 1) can be greatly increased if the water from the streams running through them can be diverted and allowed to spread over the land. A number of instances have been noticed where stockmen have plowed a furrow along the outer and higher edges of a meadow or along the side hill just above it and have diverted the water from the creeks to these furrows with excellent results. The increase in the forage produced where the water from these furrows has been allowed to seep through the ground has in some instances been quite striking. It would ordinarily require only a small outlay of work to make these furrows. As it is usually necessary to keep a herder or fence rider to look after the stock, it will take very little extra time on his part to see that the water is properly diverted to such furrows.

CONCLUSIONS.

(1) The experiments and investigations carried on during the past five years by the Bureau of Plant Industry show that the carrying capacity of mountain meadows can be greatly increased by reseeding with tame grasses.

(2) The grasses best adapted to this purpose are timothy and redtop. This is because they can be sown the most economically and will give the best returns.

(3) The introduction of timothy into a devastated mountain meadow will mean that the carrying capacity of such a meadow will be increased so that an acre will carry a 1,200-pound steer at least one month longer than it did previously. Ordinarily it will carry him two months longer.

(4) Timothy can be introduced at a cost of 95 cents per acre. If pasturage is worth 25 cents a month for each head of stock, it is reasonable to expect a return of more than 25 per cent on the cost of reseeding.

(5) Redtop will be of most value in reseeding those places that are too wet for timothy.

(6) A mixture of timothy and redtop will probably prove valuable. Timothy will give returns quickly, while redtop is more permanent and has a tendency to spread.

(7) Brome-grass, tall fescue, and orchard grass have proved to be well adapted to mountain-meadow conditions, but the cost of their introduction will prohibit their extensive use.

(8) Mountain brome-grass will readily recover the gravelly hillside areas that have been denuded by overgrazing. Where there is an abundance of succulent feed this grass is not readily grazed by stock.

(9) Slender wheat-grass may eventually prove of more value on the mountain slopes. Experiments to determine this point have not been continued sufficiently long to permit definite conclusions to be drawn.

(10) Timothy and redtop should be sown in the late autumn in order to save the expense of harrowing.

(11) Where the seed is large, as in the case of brome-grass, mountain brome-grass, etc., harrowing is strongly recommended.

(12) Plowing is ordinarily impracticable and sometimes positively injurious.

(13) Drainage, partial irrigation, and the filling in of old washouts will sometimes aid in the improvement of native meadows.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Mountain meadows in the Warner Mountains, California, where timothy can be sown to excellent advantage. Fig. 1.—A typical moist mountain meadow where all vegetation has been destroyed and a species of Veratrum has taken its place. This is an ideal place for seeding with timothy and redtop. Fig. 2.—The edge of a badly overgrazed mountain meadow where timothy should be sown. Reseeding would greatly increase the carrying capacity of this meadow.

PLATE II. Results of reseeding. Fig. 1.—A portion of a mountain meadow allowed to restore itself through protection from overgrazing. Fig. 2.—A portion of the same meadow (just inside fence) where timothy was sown in 1902. It has been closely grazed each fall since.

PLATE III. Plots at the Wenache Mountain station. Fig. 1.—Meadow seeded with redtop four years previously. The dark streaks in the picture are the young redtop heads. Fig. 2.—Meadow seeded with mountain brome-grass (*Bromus marginatus*). The boundary line of the plot is plainly shown in the foreground.

PLATE IV. Mountain meadow where the carrying capacity has been lowered by a stream cutting a deep channel, thus draining the meadow too much. Fig. 1.—General view of the meadow. Fig. 2.—The same meadow illustrated in figure 1, showing the early stages of erosion.

FIG. 1.—A TYPICAL MOIST MOUNTAIN MEADOW WHERE THE ORIGINAL VEGETATION HAS BEEN DESTROYED.

FIG. 2.—THE EDGE OF AN OVERGRAZED MEADOW WHERE TIMOTHY AND REDTOP SHOULD BE SOWN.

MOUNTAIN MEADOWS THAT SHOULD BE RESEEDED.

FIG. 1.—A PORTION OF A MOUNTAIN MEADOW RESTORED THROUGH PROTECTION.

FIG. 2.—A PORTION OF THE SAME MEADOW SEEDED TO TIMOTHY.

RESULTS OF RESEEDING.

FIG. 1.—MEADOW SEEDED WITH REDTOP FOUR YEARS PREVIOUSLY.

FIG. 2.—MEADOW SEEDED WITH MOUNTAIN BROME-GRASS.

PLOTS AT THE WENACHE MOUNTAIN STATION.

FIG. 1.—GENERAL VIEW OF THE MEADOW.

FIG. 2.—THE SAME MEADOW, SHOWING EARLY STAGES OF EROSION.

MOUNTAIN MEADOW INJURED BY EROSION.

INDEX.

O